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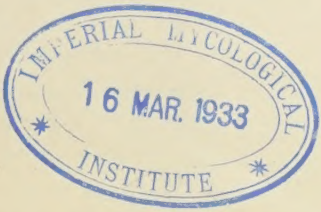

DISEASES OF PEAS IN ARIZONA

By J. G. Brown and M. M. Evans

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DISEASES OF PEAS IN ARIZONA

By J. G. Brown and M. M. Evans

INTRODUCTION

The growing of green peas in Arizona promises to develop into an important industry. Mild winters in the southern part of the State and cool summers in the central and northern parts make production possible throughout the year. Field peas too, although they are not a highly remunerative crop, probably would prove valuable in some localities for forage, green manure and cover crops, and possibly for seed. The success of these crops depends greatly upon a healthy stand.

Diseases of green or garden peas and field peas are yet limited in number in Arizona. However, some of the diseases which have appeared are very destructive. So far, practically no attention has been given by farmers to diseases until the crop has been attacked, when it often comes too late. *Prevention* of disease rather than cure is the important thing in dealing with plants, and peas are no exception to the rule. Prevention of disease may mean the special preparation of the soil to be planted, which must sometimes extend over a considerable period of time; care in choosing resistant varieties of seed, in disinfecting seed, in applying water, and in cultivating and harvesting the crop. Reasons for these statements should be clear to one who studies the following pages.

Among the diseases which are discussed in this bulletin are some which are caused by parasites which are plants, some caused by unfavorable conditions surrounding the crop, and one caused by a small roundworm. The last mentioned is the only disease caused directly by an animal which falls within the activities of this Department. Readers who do not find their questions fully answered in connection with any disease of peas are invited to correspond with the authors.

PARASITIC DISEASES

POWDERY MILDEW

Powdery mildew of peas occurs wherever the crop is grown. Although it is usually not of great importance, the disease may occasionally cause considerable loss. Unlike the downy mildew of peas, powdery mildew is favored by dry weather.

Symptoms. Pea vines affected with powdery mildew show a white mold on the stems, leaves, and pods (Fig. 1). Diseased parts may become yellowed. Badly infected plants may be dwarfed and killed.

Cause. The fungus which causes powdery mildew of peas is *Erysiphe polygoni.* The body of the fungus is made up of the white mold which is seen on the diseased parts of the plant. A large part of the mold consists of short and very fine stalks which cut off at the top of each stalk a chain of spores (Fig. 2). So numerous are the spores that they form a powdery layer which may be rubbed off the leaves and stems of the diseased pea vines like talcum powder on dusted skin. It is this powdery mass of spores which gives the name "powdery" mildew to the disease. The spores can germinate at once. They quickly spread the mildew when they are carried to pea plants by wind or other agency. They are called conidia.

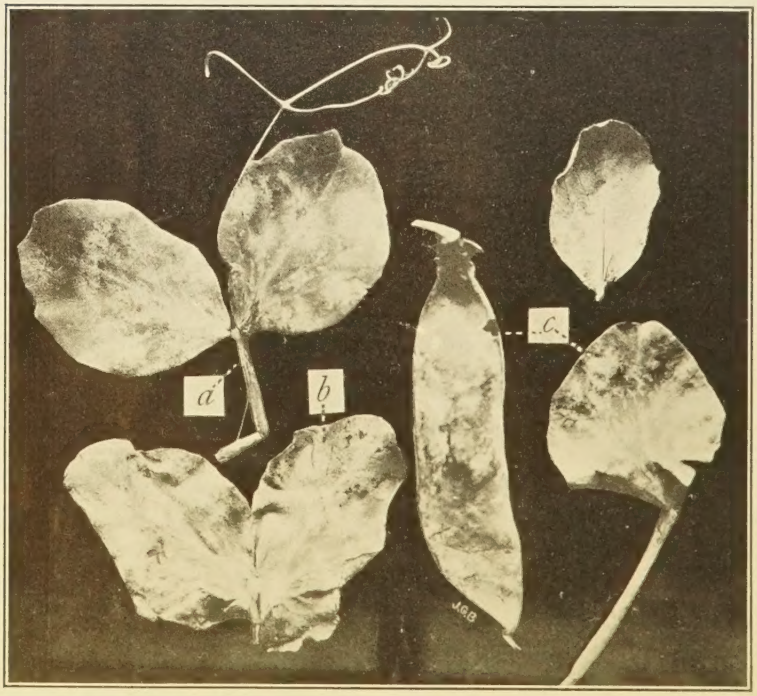

Fig. 1.—Powdery mildew *(Erysiphe polygoni)* on the pea. a. Powdery coating of spores on the petiole; b. on a stipule; c. coating of fungous filaments on pod and stipule.

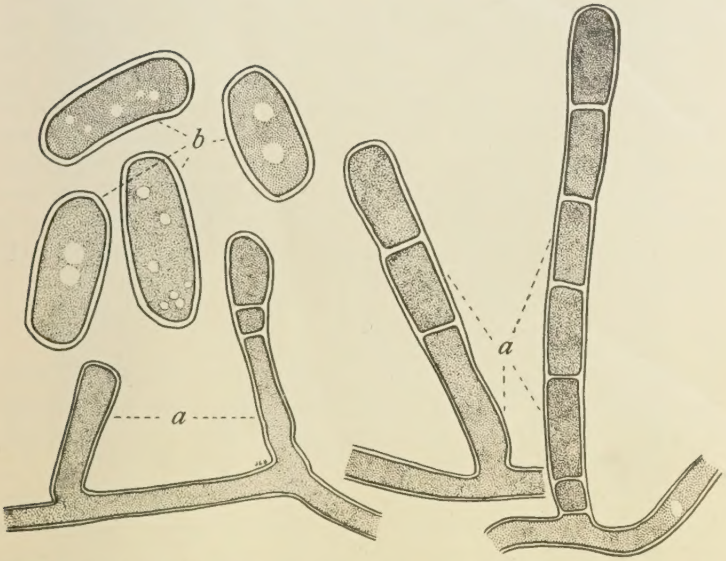

Fig. 2.—Powdery mildew fungus from the pea. a. Conidiophores; b. conidia. Magnified about 650 times.

Sometimes the powdery mildew fungus on peas makes another kind of spore. In the process small, round, black bodies which look something like fly-specks are seen in the white mold. Although these tiny black sacks are only about one three-hundredths inch across, they are important. Their walls are tough and comparatively thick. Each one of the sacks contains 2 to 8 smaller sacks. Finally, each of the smaller sacks contains 4 spores. To distinguish these spores from the white, powdery spores, they are called ascospores. Each black, thick-walled sack contains a maximum of 32 ascospores which can live over winter or through a severe dry season. Each black sack may have 32 chances to infect one new pea plant, or one chance to infect 32 pea plants in the next growing season.

Other hosts. The same fungus which causes powdery mildew on peas has been reported on many other plants including beans, cucumbers, and turnips. However, experiments indicate that there are different strains of *Erysiphe polygoni*, and that the strain on field peas will infect in addition only garden peas.

Control. Spraying with 4-4-50 Bordeaux mixture has been recommended for controlling powdery mildew of peas. When the white mold is first visible on the vines the first application of spray is made. Later a second spraying may be necessary. Dusting with fine sulfur is another method for the control of the mildew. The sulfur should be applied with one of the several types of machines made for the purpose of dusting plants. Rotation of crops has not given satisfactory results in Arizona. Pea vines make good silage, and the storing of the vines in the silo immediately followed by plowing the stubble should help to reduce infection in the succeeding crop. The recommendations apply especially to green or garden peas.

DOWNY MILDEW

Downy mildew of peas is a disease which has long been known. Only occasionally is it found in Arizona, and then only in the moister places in the field; for example, on the lowest leaves of vines in heavy stands and along irrigation ditches.

Symptoms. The most noticeable symptom of downy mildew on growing peas is connected with the reproduction of the fungus which causes the disease. The spore-bearing stalks which grow out of the stomata form *patches of grayish violet color.* The spots or patches may cover practically the entire under surface of the leaf. Sometimes inconspicuous, yellowish spots show on the upper side of the leaf.

Cause. Downy mildew of peas is caused by the fungus, *Peronospora viciae,* which also attacks broad beans and vetches. The fungus consists of colorless threads without cross-walls, which grow in the spaces between the cells of the tissues. The threads send short, finger-like suckers into the living cells of the leaf and other tender, green parts of the plant from which the fungus withdraws food and water.

Eventually spore-bearing stalks arise from the fungus threads in the plant and grow out through the stomata. In the air they branch and produce spores. When they are ripe the spores break away from the stalk on which they grow. They are carried about by currents of air and in other ways. The spores which fall upon the moist surface of a pea plant germinate and start a new infection. Like the spores most commonly found in powdery mildew, these spores of downy mildew serve for rapid distribution of the fungus; like them they are called conidia or conidiospores.

The conidiospores are short lived and must reach the host plant quickly or perish. However, another type of spore is produced by the fungus, which is resistant to unfavorable conditions. This spore is the

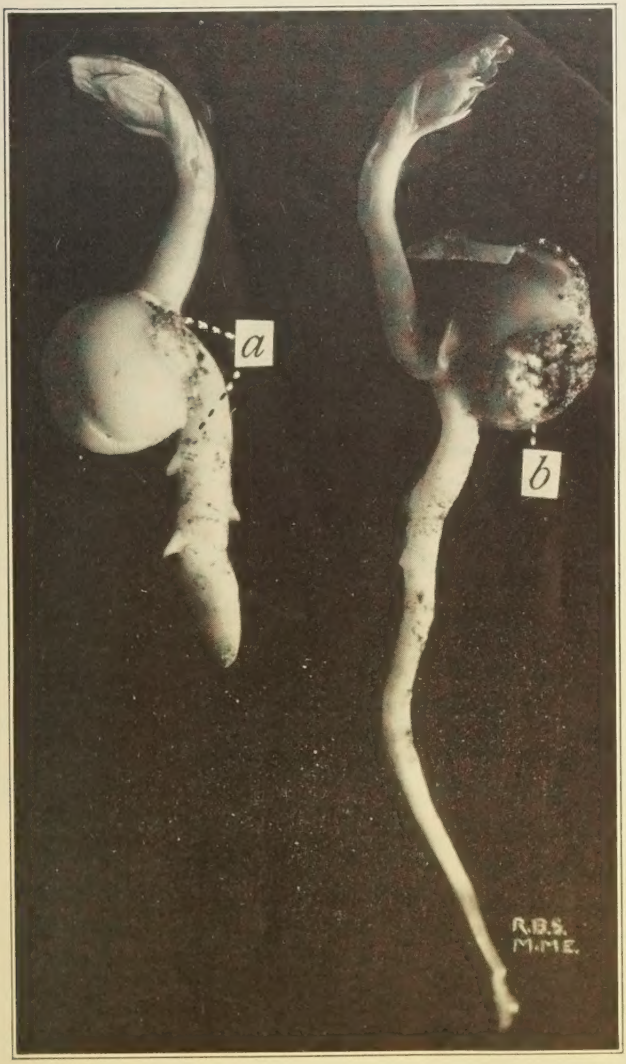

Fig. 3.—Fusarium foot rot of seedlings of Canadian field peas. The roots are in an early stage of the disease and the cotyledon, b, in a more advanced stage. a. Brown, freckle-like lesions; b. decayed spot on cotyledon of seed.

result of a sexual union between the egg and sperm bodies of the fungus. It is called an oospore or egg spore. Since the fertilization occurs in the diseased tissues of the pea plant, the resistant oospore usually lies inside the leaf. Old, withered leaves sometimes contain many oospores of the downy-mildew fungus. The oospores are thick-walled, light brown cells which are at first covered by the wall of the egg case. They germinate the next season after they are formed, and in that way carry over the infection to the new crop.

Control. So far as our records go, downy mildew of peas has never caused serious loss in this State. Spraying with Bordeaux mixture is said to control the disease in countries where it is prevalent. The destruction or plowing under of debris in fields after harvest is also important in controlling the disease.

FUSARIUM FOOT ROT

Fusarium foot rot and root rots of peas have been described from the older pea-growing districts of the United States and Europe where they have caused much loss. Diseases of this type on peas have not been reported in Arizona until recently (3).* In 1930 a Fusarium foot rot which is quite destructive was found in virgin soil in the central part of the State.

Symptoms. On the taproots of young plants and also on the cotyledons (surface of the seed) very small freckle-like brown spots show (Fig. 3, a). Later the spots or lesions enlarge, deepen, and unite. As a result of the infection the cotyledons and stem may be seriously rotted (Fig. 4, a). With the progress of the disease the lesions extend upward on the stem (Fig. 4, b) and downward on the root, chiefly in the soft tissues. Finally the seedlings are killed (Fig. 5).

In mature plants yellowing and browning of the leaves and bases of the vines result. The skin or epidermis of the root and stem base are first darkened, then later the internal soft tissues and the wood bundles. The attacked parts are rotted and the pea vines die. Little or no true wilting is seen. The symptoms are somewhat like those which result when Rhizoctonia attacks peas.

Cause. The cause of the disease is a Fusarium which was isolated in this laboratory, grown in pure culture from a single spore, and which produced the foot rot in peas when inoculated into healthy plants. It is believed to be a variety of *Fusarium merismoides Corda* (3).

* See Bibliography.

Fig. 4.—Advanced stages of Fusarium foot rot in seedlings of Canadian field peas. a, Lesions which have almost severed the taproot; b, lesions progressing upward on the stem.

Control. Although there is evidence that foot rot of peas in Arizona is carried by the seed, this means of spreading the disease is not proved. Until further investigation is completed the usual rules for the control of similar plant diseases should be followed. The rules include the selection and treatment of the best seed obtainable, the planting of fields not cropped to peas within a preceding period of 4 or 5 years, rotation of crops, and field sanitation. The practice of making ensilage of pea vines after the pods are harvested is a good one from the standpoint of

plant diseases. The stubble should also be plowed under as soon as possible after harvest. Certainly old vines should not be left in the field to harbor diseases.

RHIZOCTONIA ROOT ROT

This disease attacks field peas, garden peas, and sweet peas. It is common and widespread in the State, especially in the spring when the nights are cold, and especially in the heavier soils. The fungus which causes the disease also attacks potatoes (black scurf), cotton (sore shin), beans, strawberries, and many other cultivated as well as wild plants which grow in Arizona.

Symptoms. Peas infected with Rhizoctonia may show yellowed leaves and stunted vines (Fig. 6) which finally die. However, in early stages of infection there may be no symptom on the plant above ground to disclose the attack. At this time the roots and base of the stem show small, brown, somewhat irregular spots (Figs. 6, a; 7, 1; 8, c) which later deepen in color. As the disease progresses the roots of the young

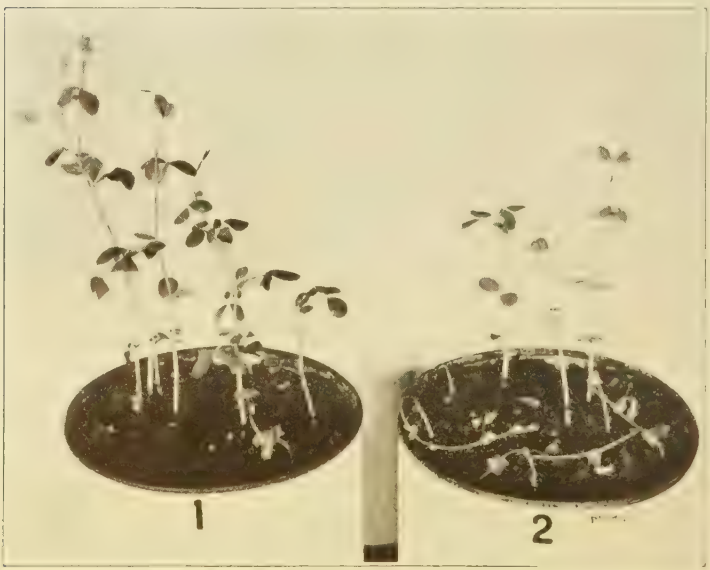

Fig. 5.—Canadian field peas inoculated with spores of Fusarium May 8, 1931; photographed May 27. 1, control; 2, inoculated peas.

Fig. 6.—Rhizoctonia disease of sweet peas; sick plants (1) compared with healthy plant (2). a, spots on roots; b, constricted roots

plants become constricted (Fig. 6, b) and the plants die. The effect of the disease depends considerably upon the size of the plant when it is infected. Infection of seedlings usually results in extensive killing; older plants often survive

Cause. *Rhizoctonia solani*, the fungus which causes the common root rot of peas, is a soil dweller. It can live upon organic matter in the soil. We have found it in abundance on decaying alfalfa which had been plowed under as a green-manure crop

PLATE I

Rhizoctonia disease of peas. Fungus threads (1) beginning to form a resting body like that shown in Fig. 8; branching of a fungus thread (2); fungus threads on skin cells of root (3). Magnification of Figs. 1 and 2, about 680 times; Fig. 3, about 260 times.

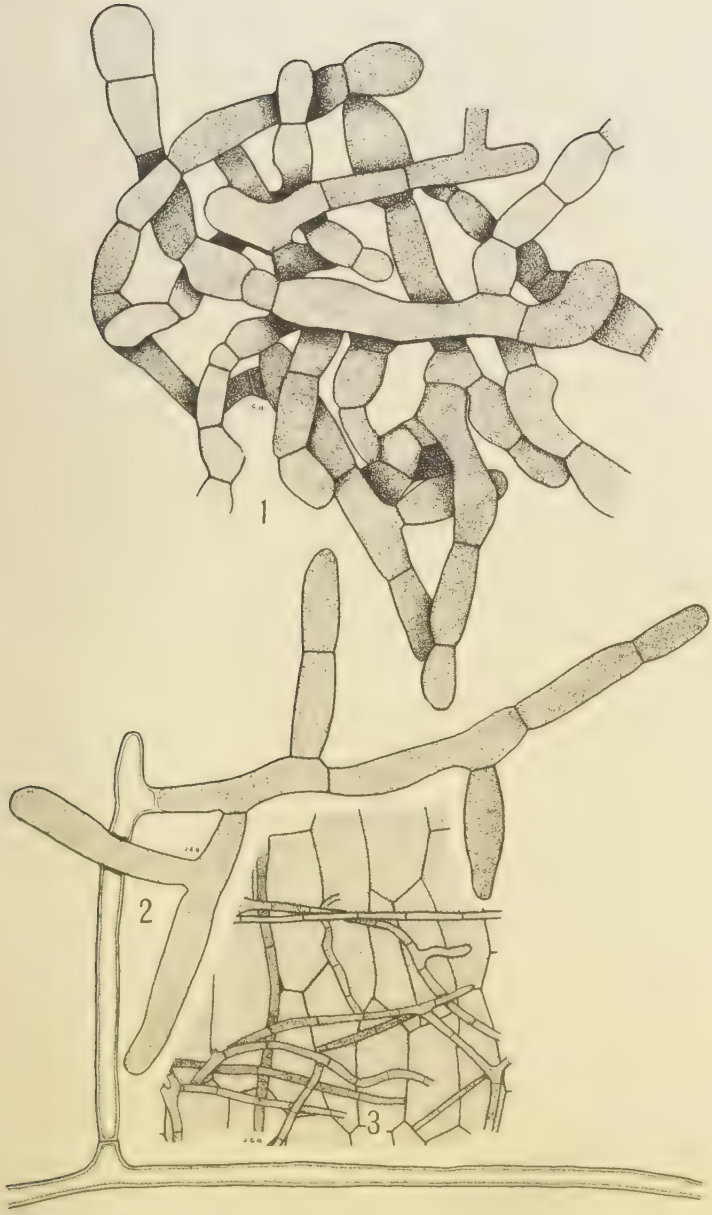

PLATE I.

Young filaments of Rhizoctonia are colorless, but they become brown with age. On the roots and stem bases of infected pea plants (Plate I, Fig. 3) they branch abundantly (Plate I, Fig. 2), penetrate the epidermis, and kill epidermal and deeper cells. This growth of the fungus causes the brown spots previously mentioned. The lesions or spots are similar in color to those caused by some Fusaria, but they appear to be somewhat more irregular in form when studied under the lens. Another difference, in the case of the Fusarium foot rot previously described in this bulletin, is the deep cotyledonary lesion which is usually found on seedlings attacked by the Fusarium. From the spots of dead tissues the threads of the fungus continue to grow farther into the plant. Not only do they injure by robbing the plant of food and water, but they also make possible the escape of water through the dead spots in the skin.

At length the fungus develops resting bodies or sclerotia (Fig. 8, r) which are brown to black interwoven masses of threads with short, irregular, thick-walled cells (Plate I, Fig. 1). The sclerotia resist drying and other severe conditions, and afterward they can produce a new fungus body which can attack a new crop. How long the sclerotia can survive in the dry climate of Arizona is not definitely known, but observations in the field indicate that they may remain alive for two or more seasons.

Besides the sterile or sporeless stage, *Rhizoctonia solani* also has a spore-bearing stage. The latter is known under the names of *Corticium solani*, *Corticium vagum* variety *solani*, and *Hypochnus solani*. The threads of the fungus on which the spores are borne form a white or grayish white mass on leaves and vines in contact with the soil. The spores are developed on microscopic branches (clubs or basidia), and are termed basidiospores. We have never observed the spore stage of *Rhizoctonia solani* on peas in Arizona, but the senior author found it in abundance on potato plants in southern Apache County during the summer of 1931. The stage probably occurs on peas under favorable conditions.

Control. Since *Rhizoctonia solani* lives in the soil and on numerous weeds as well as on cultivated plants, its control is difficult. That the fungus, as a saprophyte, is quite adaptable to soils widely different in chemical reaction is shown by its distribution. Not only is the fungus abundant in the acid soils of the Eastern states, but also in the alkaline soils of the West. There is evidence that, as a parasite, it varies in virulence under different conditions with respect to the kind and nature of the host plant; possibly also at times under different soil conditions.

Crops of potatoes after potatoes, cotton, and beans are more severely attacked than when planted after other crops. There is also evidence that attacks are more severe on plants which are not thrifty as compared with thrifty plants. Cotton planted during the cool weather of March and April sustains a heavier loss from the attack of *Rhizoctonia solani* (sore shin) than the same variety of cotton planted in the same soil in May and June. Attacks of Rhizoctonia are often more virulent on young plants than on older ones, and this is true of peas as well as cotton. Although excess moisture in the soil favors the fungus in its attack on peas and other plants, *Rhizoctonia solani* can and does cause loss under conditions of optimum soil moisture for the host plant. Some areas of desert soils in southern Arizona appear to be too dry for Rhizoctonia, or possibly their sparse vegetation is unsuited as hosts. When such soils are broken, several successive crops of susceptible plants have been grown on them without any evidence of infection, which indicates that the fungus is absent.

Rhizoctonia root rot of peas cannot be controlled by any single method, but a combination of methods must be used. Clean cultivation, wise rotation of crops, and judicious use of irrigation water and fertilizers should decrease losses. Weeds harbor the fungus and should be kept out. In choosing a rotation of crops small grains, corn, and sorghums are valuable. Irrigation should be moderate. In the cultivation of garden peas, planting in rows on ridges and stirring the soil between irrigations are advisable. Fields known to be infected with *Rhizoctonia solani* and which are to be planted to a fall crop of peas should be worked in a dry condition during the summer.

For small patches of garden and sweet peas we have used chemical disinfectants to advantage. Mercuric chloride solution (POISON!) in the strength of 1:1000, applied in sufficient quantity to wet the soil to a depth of 1 inch, quickly checks damping-off of pea seedlings with little or no chemical injury to the plants. Other chemical disinfectants such as formaldehyde, Bordeaux mixture, and carbolic acid have been suggested for use on limited areas of infected soil before peas are planted. The formaldehyde solution is made by adding 1 pint of formaldehyde to 30 gallons of water, and the quantity used is 1 gallon per square foot. The soil is afterward covered for 2 days with heavy burlap or canvas, then permitted to air before it is planted. Standard Bordeaux mixture is diluted to half-strength and also applied to the soil at the rate of 1 gallon per square foot. Carbolic acid (phenol) was used for killing Rhizoctonia in soil by Shaw (16). The solution was made by adding 1 ounce of the acid to each gallon of water, and the

Fig. 7.—Rhizoctonia lesion, *l*, on base of stem of pea plant.

Fig. 8.—Root of pea plant with Rhizoctonia disease *c*, lesion or decayed spot; *r*, resting body of fungus

rate of application was approximately 1 gallon of solution to 4½ square feet of surface.

TEXAS ROOT ROT

Peas are susceptible to injury from Texas root rot which also attacks many other taprooted plants, both wild and cultivated. The disease is found in all agricultural districts up to altitudes of 3,500 feet in central Arizona and even higher in the southern part of the State. Texas root rot has been reported from Arizona, Arkansas, southeastern California, New Mexico, Oklahoma, Texas, and Mexico (4).

Symptoms. Texas root-rot spots in the field usually are more or less circular. Gradually the spot enlarges until it may include in one season areas several yards in diameter. In the case of perennial plants like alfalfa, spots of root rot an acre or more in extent are not uncommon. The presence of the susceptible crop serves to show the location of the fungus in the soil, but the removal of the crop does not remove the rot. The root-rot spot often appears the next year in the same place if a susceptible crop is planted.

The disease behaves in much the same way on the different plants which it attacks. Sick plants are easily pulled from the soil, when some of the roots may be found to be partly or entirely rotted; other roots have the bark killed, so that the woody part easily slips out of the bark (cortex); still other roots fail to show rot but have dirty gray to tan threads and strands on the surface and fungus threads in the wood vessels. In the case of peas, dying plants frequently show practically complete destruction of the root system. The rotting of the roots and clogging of vessels reduce the absorption and conduction of water so that wilting and death follow. The fungus does not penetrate the part of the plant above ground.

Cause. Texas root rot is caused by a fungus now called *Phymatotrichum omnivorum* but formerly referred to under the name of *Ozonium omnivorum*. The fungus lives in the soil on the roots of plants in the form of slender filaments and large strands. The strands look not unlike a frayed piece of rope when they are viewed under the microscope. From the filaments and strands branches may penetrate into the vascular system of the root.

During the summer rains the fungus sends to the surface of the soil filaments which are often so numerous that they form gray, velvety patches 1 to several feet across. The patches of the fungus mainly consist of spore-bearing threads. So abundant are the spores under favorable conditions of temperature and moisture that they make a light

brown layer one-eighth to one-quarter inch in thickness. The spores do not readily germinate in artificial cultures. At present it is not known that they are able to start the root-rot disease in plants.

Another structure produced by the fungus of Texas root rot is a small resting body or sclerotium which recently has been described (12). The resting body is a mass of thick-walled cells which is resistant to conditions under which the active fungus threads would die. It has been found deeply embedded in the soil and has been successfully used in inoculating plants. The presence of resting bodies in the soil greatly increases the difficulty of controlling the Texas root-rot disease. Fortunately the resistant resting bodies do not appear to be nearly so widespread as the active stage of the fungus.

Control. Although we have observed occasional cases of Texas root rot in peas, but little damage is caused to the crop by the disease. The fungus concerned is less active in late fall, winter, and early spring where peas are grown in southern Arizona. In the central and northern parts of the State at higher altitudes where peas are grown in summer, the fungus which causes Texas root rot is probably absent.

In spite of the fact that peas may be grown in southern Arizona in winter on soil infected with the root-rot fungus, the practice of planting a susceptible crop is a bad one. Certainly the farmer who desires to rid his fields of the destructive Phymatotrichum will not knowingly plant susceptible crops, either in winter or in summer, in infected fields; neither will he permit taprooted weeds to exist in such fields.

Fallowing without irrigation and *with complete extermination of weeds*, for a period of 2 or more years; the growing of resistant crops such as corn, sorghums, barley, and wheat; the use of ammonium sulfate and barnyard manure, have been suggested for reducing infection of the soil with Texas root-rot fungus (18). A combination of the control methods suggested, used by persevering farmers, should produce results. The farmer whose land is infected with the root rot must expect to make some sacrifice in order to get rid of the disease. He must discontinue to grow cotton and alfalfa. He may be obliged to fallow some fields. Every year that he delays control measures, the root rot is growing farther into his fields. The time to control root rot cheaply is when the first small spot appears in a field. At that time a few cents' worth of formaldehyde will stop farther advance of the fungus.

BACTERIAL BLIGHT

Bacterial blight of peas was first described from Colorado in 1916 (15). Since then it has appeared in Delaware, Florida, Illinois,

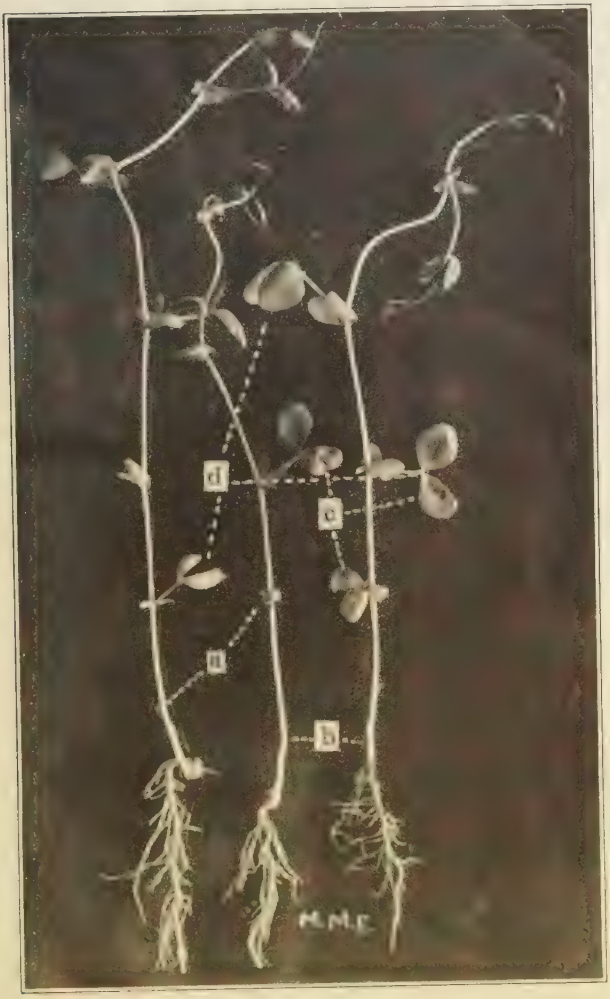

Fig. 9.—Bacterial blight of peas. Seeds planted October 30 and resulting plants photographed November 24. Water-soaked stipule (a); stem lesions (b); leaf lesions (c); yellowing leaves (d)

Indiana, Maryland, Michigan, Montana, New York, North Dakota, Oregon, Pennsylvania, South Carolina, Wisconsin, and California. Losses from bacterial blight in these states have been as high as 50 percent of the crop in some fields. They have resulted from reduced stand; the killing of leaves, stems, flowers, and pods, and the spotting of pods which renders green peas unsalable. Bacterial blight appeared in Arizona in 1930 (3).

Symptoms. Infected spots, wherever they may occur on the pea plant, have at first the water-soaked appearance which accompanies most bacterial diseases of plants. Small drops of colorless to yellow bacterial ooze may be seen on the lesions. As infected spots become older they turn brown to black.

The spots are very small when they are first visible. They may begin on the stem near the soil line and extend upward to the stipules and leaves, or they may be scattered (Fig. 9) over the lower part of the plant on the lowest stipules and on stem and leaves.

Fig. 10.—Bactrial blight of peas. The seedlings at the right were inoculated with the germ of the disease 8 days before the photograph was made; seedlings at the left were not inoculated.

Fig. 11.—Bacterial blight of peas. Water-soaked spots on the pods.

Young plants under 6 inches in height frequently wilt and die (Fig. 10) as a result of the disease, which causes gaps in the drill rows. Some of the dead plants show only a few bacterial spots or a slight yellowing of the stipules and leaves. In these plants the bacteria have reached the water-conducting vessels. Plants with larger spots on the stem may lose turgidity and wither down more slowly.

Older plants which have branched usually show yellowed leaves and stipules on one of the branches, first on the lower part, then a progressive yellowing upward. The entire branch may be killed and also new ones which develop below the primary infection. Stunting of the later branches may also be noticed. When the infection reaches only a few internodes (parts of the stem between the leaf attachments) near the ground the plant usually outgrows the disease.

Infected flowers and young pods are killed. Older pods show either rounded water-soaked spots (Fig. 11) which later become yellow and then brown, or a water-soaked strip along the back. From the infections on the outside of the pod the bacteria penetrate through the wall

of the pod into its cavity. There they grow in a slimy layer over the inner surface. By attacking the small stalks which attach the peas to the pod, they kill the young pea seeds.

Bacteria which penetrate the seed stalk may also enter the small opening of the young seed and check the growth of the seed. If the seed is more mature when the bacteria enter, growth of the seed is not checked but a water-soaked spot may result. When the growth of the bacteria in the seed is limited, there may be no external evidence of infection of the seed. Although such seed looks healthy, the farmer who uses it may have serious losses in his fields.

To summarize, the relations of the bacterial blight to the pod and seeds are as follows: The pod may be spotted and rendered unsalable but the seed is not infected, or the seed may be coated with bacteria which penetrate into the cavity of the pod; young seeds may be killed when the bacteria attack the seed stalk, or the seeds may mature with only a small, water-soaked spot to indicate that they are diseased; finally, the bacteria may enter the seed without causing a water-soaked spot or any other sign of their presence, so far as the unaided eye is concerned.

Cause. The cause of bacterial blight of peas is a germ or bacterium which was first named *Pseudomonas pisi*, later called *Bacterium pisi*, and is now known as *Phytomonas pisi*. It is a small, swimming, grayish white rod which can enter the plant through stomata and wounds. It can live on and in pea seeds for 10 months, possibly longer, but it is said not to survive the winter in the soil. It first enters the field with the seed in most cases. Afterward it may be spread by wind, irrigation water, the contact of diseased with healthy plants, and probably in other ways. A few diseased plants from infected seed may become distributing centers of infection for the field. This fact points to the importance of clean seed.

Conditions favoring bacterial blight. Bacterial blight is said to be favored by heavily manured soil and by sandy soil where moisture is limited. Plants on heavily manured soil have an abundance of young tissues in which the bacteria of blight grow rapidly. Dry, sandy soils lack enough moisture for vigorous growth of pea plants and the diseased plants quickly die instead of outgrowing the blight. Moisture in the air permits the accumulation of bacterial ooze on lesions of sick plants and in this way makes easy the spread of the disease. Mechanical injuries greatly increase infection, although infection can take place through the natural openings (stomata) of the plant. Wind and late spring frosts favor blight.

Plants subject to blight. The bacterium of pea blight can cause disease in cowpeas, sweet peas, everlasting peas, hyacinth bean (17), as well as in field and garden peas. It does not affect alfalfa, crimson clover, mammoth clover, sweet clover, and garden beans. Extra Early and Lightning Excelsior varieties of garden peas are somewhat less susceptible than the Telephone variety. Among varieties of forage peas Shanghai, Solo, Kabilya, Killarney, Chang are stated to be less susceptible than many others (11).

Control. Resistant varieties of peas offer the best opportunity for escaping losses from bacterial blight. Until the results of experimental work have become available, local selection of seed from resistant plants should be encouraged. Fields of peas most severely attacked by blight are best for the selection of resistant plants. The seeds from a healthy plant which stands alone in the midst of badly diseased ones should always be saved.

Greater care on the part of seedsmen who produce seed peas is desirable. An examination of the seeds of several varieties of garden peas offered for sale in Arizona showed the presence of seed infected with the germ of bacterial blight. Local seed dealers are not equipped to test seeds for bacterial and fungal parasites, but they can at least use every effort to encourage the seed producers from whom they purchase their stocks to grow seed free from disease. Farmers should buy the best seed procurable and also treat the seed to reduce infection from germs which may be carried on the surface of the seed. The use of a seed-plot, in which rogueing and seed selection are combined, would be of great help in eliminating bacterial blight and other diseases of peas.

The treatment of pea seeds may be carried out by using a solution consisting of 1 pint of 40 percent formaldehyde in 22 gallons of water. The seeds are soaked for 20 minutes, then planted. This treatment is a cheap one. Another good treatment is to soak the seed for 10 to 20 minutes in a 1:1000 solution of mercuric chloride. The solution of mercuric chloride is made by dissolving 1 ounce of the chloride in a quart of hot water, after which enough cold water is added to make 8 gallons. The solution is a strong poison. The seeds should be treated just before they are planted.

If a dust treatment is desired, the organic-mercury compounds may be used. They are poisonous and must be handled accordingly. Directions accompany each package. In using dusts care should be taken to obtain a thorough coating of the seeds. For this purpose a dusting machine may be made by running a diagonal axle through a steel barrel which has been fitted with a door at one end. For turning the barrel a crank is adjusted to one end of the axle. Then the barrel is suspended

by resting the ends of the axle in notches in two ordinary saw-horses such as carpenters use.

As a result of treating pea seeds with organic-mercury compounds Clayton (6) reports an increase in stand of 3 to 56 percent, and an increase in yield of 11 to 57 percent. It must be remembered, however, that seed treatments applied to the surface of the seed will not kill germs carried inside the seed. Such treatments reduce infection in the field by killing surface-borne germs on the seed, but they cannot entirely eliminate diseases like blight. However, usually few diseased plants result from the internal infection of the seed, and these may be rogued out of the field.

Mechanical injuries from hailstorms, sand storms, and wind have been shown to increase infection in the case of pea bacterial blight. Nothing can be done to lessen injury from hailstorms, but windbreaks of tamarisk or other suitable hedge plant should reduce the effects of sand storms and wind. Since windreaks are valuable protection for crops other than peas, the investment is a good one, particularly on the west side of farms bordering areas of dry desert soil.

The rotation of crops, usually advised for the control of plant diseases, although valuable in maintaining the fertility of the soil, does not necessarily affect bacterial blight of peas.

ROOT KNOT

Root knot of peas is important in Arizona, mainly because the disease is held over in the soil by the crop. Although losses are insignificant, peas and other susceptible plants should not be grown where the root knot is known to exist. The disease is a bad one, for it can attack several hundred different kinds of plants. Originally our desert soils, like those of other arid countries, were free from the root-knot parasite (1), but infection started some years ago, probably through the importation of nursery stock. Now the disease is bad in a few districts and spreading not only on nursery stock but also in many other ways.

Sypmtoms. There may be no symptoms above ground when the infection is light and there are few knots on the roots of the pea plants. Increased infection, with growth in size and numbers of the knots, results in dwarfing the plant. The reason for this is the diversion of food materials and their use in building up knots instead of normal tissues; also the interference of the knots with the flow of sap in the roots. The plant may finally shrivel and die, or it may remain alive. Pea plants with numerous root knots usually bear a small crop or none at all.

Fig. 12.—Dwarfing of field peas caused by root knot. Infected plants at the sides, healthy plants in center.

Since symptoms of root knot are often absent above ground, the farmer remains unaware of the disease and believes that poor yields are caused by low soil fertility. Examination of the roots, however, reveals the presence of root knots (Fig. 13). Care must be taken not to confuse the root knots with the bacterial nodules which are beneficial. The knots are spindle-shaped swellings in the root, itself, while the nodules are attached to the side of the root (Fig. 14). The knots in pea roots are not branched like many of the bacterial nodules.

Cause. Root knot of peas and more than 500 other plants is caused by a small roundworm, *Caconema radicicola.* The parasite not only causes disease directly, but it also weakens plants and paves the way for other parasites. It belongs to the class of animals which includes the hookworm and the vinegar eel. The life cycle is as follows.

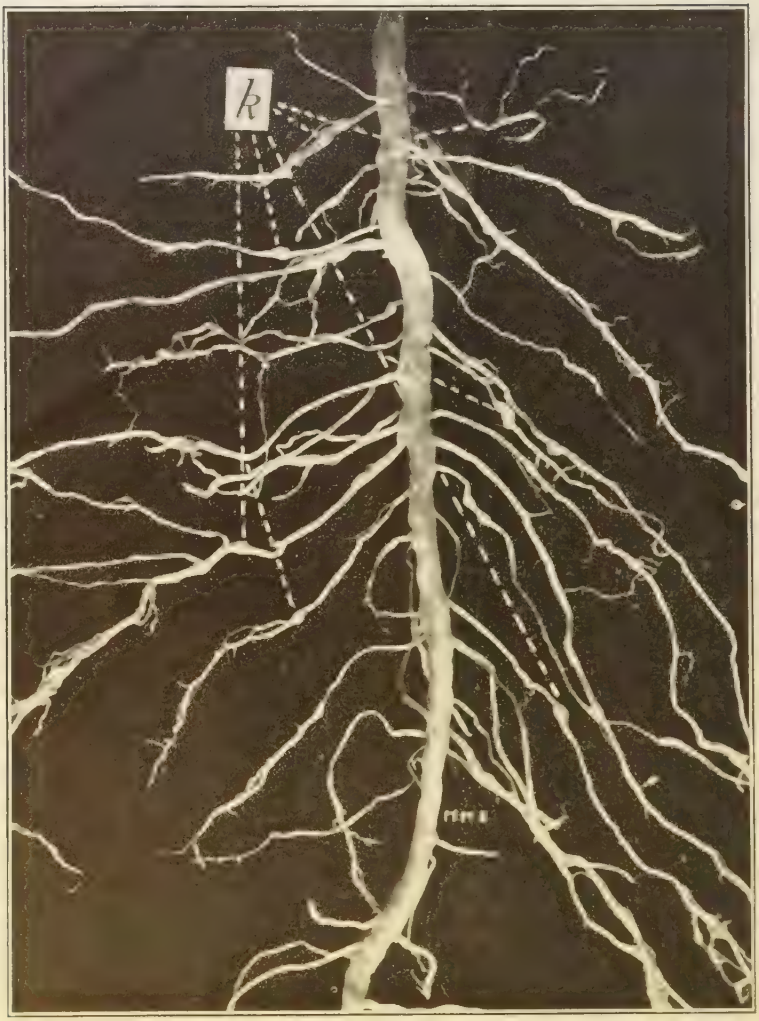

Fig. 13.—Roots of field pea showing nematode galls (root knot).

From a colorless, oval, transparent egg $^1/_{250}$ inch in length the young worms hatch, usually outside the body of the mother but sometimes inside. When the worms reach the tender tips of roots they pierce the

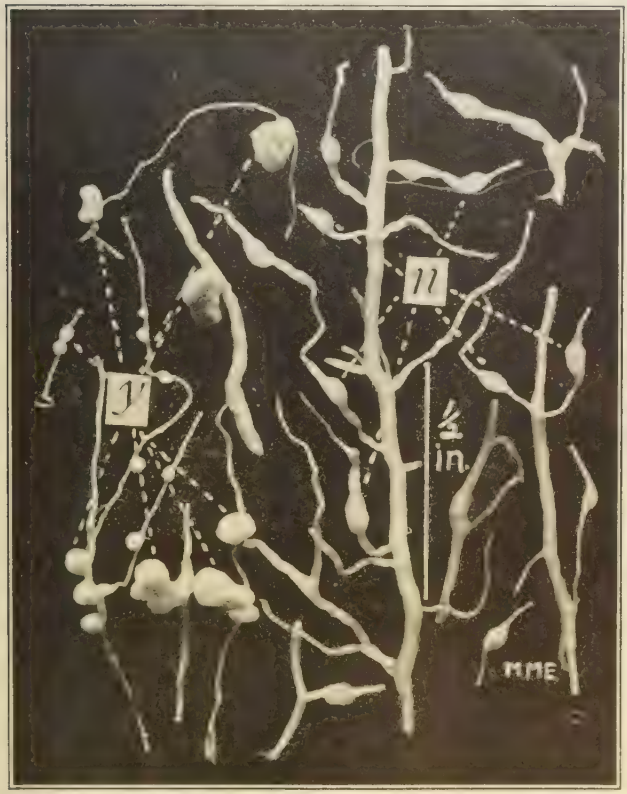

Fig. 14.—Root-knot galls (n) and bacterial nodules (n') on roots of field pea. Magnification nearly 3 times, as shown by natural line at right

tissues. At this time they are 1/32 inch long. Their presence causes a local stimulation of the root, probably through the action of some chemical substance in their saliva. The root grows locally and the swelling which results is a "root knot."

The young male worm matures in 3 to 4 weeks, seeks and fertilizes the female, and dies. The female worm enlarges to a pear-shaped form 1/16 inch long and begins to lay eggs at the rate of 10 to 15 per day. She may deposit a total of 60 to 500 eggs (Fig. 15). Under favorable con-

ditions the eggs hatch in 2 to 6 days, otherwise they may remain dormant for a varying length of time. The time required for a generation from egg to egg is 3 weeks to 2 months. The young worms inside the root knots are set free by the decay of the root.

Passage of the worms or nematodes through the soil is very slow. If their spread in the field depended upon that manner of dispersal, the disease would be less troublesome to eradicate. However, the parasite is carried about in many ways. Irrigation water in this country is an

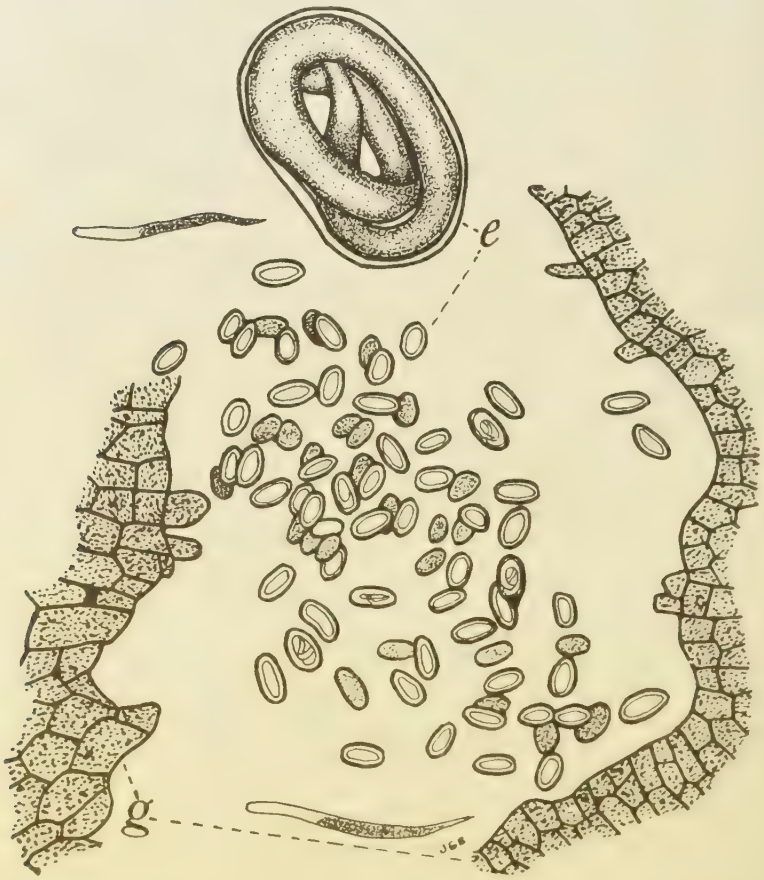

Fig. 15.—Part of a section through a nematode gall showing edge of gall (g); eggs of nematode (e), and two adult worms; the egg at the top contains a young worm and the drawing is highly magnified.

important factor. Soil on the feet of men and farm animals; on tools, implements, and vehicles, and on the roots of plants efficiently spreads the infestation. Indeed the exchange of rooted plants from infested soil to clean soil forms one of the commonest means of dispersal, and a means that is difficult to prevent.

Control. Many methods have been proposed for the control of root knot and some of them are practicable. Where the land must be used in order to obtain an income during the attempted control of the parasite, rotation and diversification of crops combined with clean culture is the best method.

Rotation and Diversification of Crops.—Rotation of crops will differ, not only in different parts of the State but also in different districts and even on different farms in a district. Each farmer should work out his own rotation. In doing this he must remember that the crops used must be resistant to root knot. Such crops are few.

Among the crops which are resistant to root knot (1) are velvet beans (14); certain varieties of cowpeas; sweet clover *(Melilotus indica);* peanut; wheat and corn except under conditions very favorable to the nematode; some varieties of barley and oats; rye; sorghums, milos, and Kafirs; crab-grass *(Syntherisma sanguinalis);* Johnson grass.

The velvet bean is practically immune to root knot; Iron, Brabham, and Victory cowpeas are highly resistant but less so than the velvet bean. The bush velvet bean has an advantage over the running varieties, for it permits cultivation and destruction of weeds, whereas the vines of other varieties are in the way of the cultivator and hide weeds. Where it will grow, the velvet bean should be used as a summer crop followed by resistant grains. At somewhat higher altitudes where the velvet bean does not grow well, cowpeas may be substituted for it. Still higher in the State resistant grains may be alternated with sweet clover where the need of a leguminous crop is shown.

With the bush velvet bean one summer is said to be sufficient to reduce the nematode population so that a good crop of susceptible plants can be produced. In most cases however, a 2- to 3-year rotation with resistant crops will probably be necessary in badly infested soil before peas can be grown. The time will depend somewhat upon the kind of peas to be planted. Garden peas are more susceptible to injury from nematodes than field peas. The period in which resistant crops must be grown will also vary with the soil. In some cases a 3-year rotation will not be long enough. With every series of rotating crops *weeds must be kept out.*

Drying.—The killing effect of dry soil on nematodes has been observed by numerous investigators. Recently Godfrey and Morita (7) have published some exact data on the subject. They say, "Larvae are killed at 43 degrees C. (107.5 degrees F.) in 10 minutes and at 53 degrees C. (127.5 degrees F.) instantly. Egg masses are killed at 48 degrees C. (118.5 degrees F.) in 10 minutes and at 58 degrees C. (136.5 degrees F.) instantly. Complete dryness kills larvae in 3 minutes and egg masses in 2 hours. Drying at 70 percent relative moisture kills larvae in 10 minutes and egg masses in 4 hours. Free eggs are killed more quickly than those in egg masses. Egg masses buried within roots survive for 48 hours in complete dryness, for 5 days at 60 percent, for 7 days at 70 percent, and indefinitely at 90 to 99 percent. . . . Sunlight killed larvae in 25 minutes, egg masses in 8 hours, free eggs in 1½ hours. Combined sunlight and drying killed larvae in 2 minutes, egg masses in 30 minutes, and eggs within roots in 8 hours." The parasite was killed in soil 10 inches deep by 4 months' drying with stirring.

Drying the soil appears to be the best method for killing nematodes in Arizona, where the use of the land can be spared. Since stirring hastens the death of the worms, the soil should be dry-worked as deeply and as frequently as possible. No weeds should be allowed to grow. This treatment, applied during the driest months of the year, should not only kill the nematodes which cause root knot but should also benefit land infected with the fungus which causes Texas root rot.

Drying is equally adaptable to large and to small plots of ground. It may also be used by the gardener and nurseryman in killing nematodes in soil exposed in seed boxes and flats. The two important disadvantages of the drying method are the loss of the use of the land during treatment and the burning out of organic matter in the dried soil.

Chemicals.—No entirely satisfactory chemical has been found for combating the root-knot nematode, although a few may be used successfully on small infested areas and on small quantities of soil. In general, the chemicals tried have been too expensive for extensive infestations. Furthermore, many of them are injurious to crop plants when applied in amounts large enough to kill nematodes. Newhall (13) lists the following chemicals which have been used in the attempt to control the root-knot parasite.

Acetic acid, ammonia vapor, ammoniacal liquor of gas works, ammonium silicofluoride, ammonium sulfide, ammonium sulfate, ammonium sulfate plus lime, Blackleaf 40, benzol vapor, dry and liquid calcium carbide, calcium sulfate, carbolic acid, carbon disulfide, carnallit, copper sulfate 20 percent, cresol, cresylic acid, cyanamide, Cyanogas, formalde-

hyde, gasoline, hydronaphthol, kerosene emulsion, kainit, lead arsenate (acid), lime (quick, slaked, and as lime water), lime-sulfur, lye, magnesium sulfate, manganous sulfate, naphthalene, paradichlorobenzene, phenol (Lettle's solution), potassium chloride, potassium cyanide, potassium hydroxide, potassium permanganate, potassium sulfate, potassium sulfide, potassium sulfo-carbonate, potassium xanthogenate, sulfuric acid, sulfur (ground and inoculated), superphosphate, tobacco dust, tobacco dust plus kainit, tobacco decoction, unleached ashes, and zinc sulfate.

Calcium cyanamide was thought to be promising because it possesses both disinfective and fertilizing properties. However, when used in quantities large enough to kill the nematodes it also injured crops. Furthermore, the nematodes were not eradicated but the population was simply reduced.

Formaldehyde was used by Bessey (1) on nematode-infested soil at the rate of 1 to 2 gallons of dilute solution per square yard of soil surface. The solution consisted of 1 part of 36- to 40-percent formaldehyde to 100 or 200 parts of water. It was sprinkled on the surface of the soil or poured in deep furrows which were leveled after the solution had soaked into the soil. The treatment freed most of the upper layer of soil from nematodes. He concluded that more solution per square yard might penetrate deeply enough to kill all nematodes in the soil. We have used this chemical to disinfect small areas and in sterilizing small quantities of soil before planting. A strength of 4 or 5 percent is recommended.

Flooding.—The flooding of infested fields for the control of nematodes is not satisfactory, although plants which grow naturally in soil saturated with water have very few galls. Jones (10) found that flooding gall-infested soil for a period of 28 days did not eradicate the nematodes.

PHYSIOLOGICAL DISEASES

The physiological diseases of peas and other plants are often caused by some unfavorable condition outside the plant. Freezing temperatures, intense heat and light, drought, excessive soil moisture, injurious salts in the soil, or mechanical injuries may render a plant abnormal or diseased. These unfavorable conditions act upon the plant in various ways. For instance, the grinding action of sand in a strong wind may wound pea vines and leaves. The plant starts to heal the wounds. For this purpose its stored foods, such as sugars and starches, are needed.

The stored foods must be broken down into simpler products before they can be used to build new tissues. The process of breaking down stored foods is an oxidation or slow burning. When the process of breaking down or oxidizing the stored materials is in rapid progress, delicate instruments usually show a rise in the temperature of the plant, which is comparable to fever in animals. Any physiological disease which does not quickly kill the plant may thus weaken it by causing it to use up its reserves. Physiological diseases may also be followed by parasitic diseases. In the case of the pea plant the unprotected, injured surfaces resulting from a sandstorm may be invaded by the bacteria which cause blight, or by other parasites. Thus the physiological diseases are important in at least two ways: directly, they cause a weak, diseased condition of the plant; indirectly, they frequently lead to infection with destructive parasites.

DROUGHT INJURY

Drought is defined as dryness; want of rain or water; especially such dryness of weather or climate as affects the earth, and prevents the growth of plants; aridity.

In irrigated countries there is often more danger to crop plants from the dryness of the air, especially air in motion, than from the dryness of the soil in which the crops are growing. The moisture of the cropped soil is under the control of the farmer. Not so, the moisture of the wild desert land. Winds sweeping over the latter become dry and hot. When they reach a growing crop they so hasten evaporation from the foliage (transpiration) that the water-loss can be replaced by the plants only with difficulty, or only partially. The farmer frequently finds at such times that irrigation does not save his crop from "leaf scorch" or more severe injury, for the water-transportation system of the plants often lacks the capacity to meet the sudden excessive demand for water.

To understand the physiological effect of drought or water starvation one must have in mind a picture of the conditions normally existing in a healthy plant. The plant is mainly made up of water which enters through restricted porous parts of the root and is then called sap. Water can easily escape from the plant only through the natural openings (stomata) of the green parts, and through the root hairs and tips of the roots when the soil is very dry.

In the sap inside the plant are dissolved substances of which some are food and food materials for the plant, and others are waste substances. The dissolved substances are found in all living cells or units of the plant, and many of them are free to move slowly from cell to cell.

They may also be carried rapidly in the dead wood vessels and the sieve cells, which are tubes running through the roots and stems up to buds, leaves, flowers, and fruits. The dissolved substances inside normal living cells, which cannot pass through the cell membrane, "draw" water into the cell; the finer they are divided, the greater their "pull" on water.

Let us suppose that the plant is inactive for the moment. You must understand by "inactive" that the plant is not growing but that it is "breathing," for breathing is always going on in living things. We will suppose, too, that the breathing is uniform everywhere in the plant. Breathing or respiration is really a slow burning or oxidation. During the process of respiration sugars, fats, and proteins are slowly broken down into simpler products. Since the plant is not growing anywhere and respiration is uniform throughout the plant, the dissolved substances are in balance, or nearly so. However, if a disturbance takes place in any cell or group of cells the effect soon reaches neighboring cells, and the balance is upset. For instance, if a group of cells like a bud starts to grow, it at once becomes the center of consumption of water and food materials. The use of the water in the bud lowers the concentration of water in that particular spot, and more water flows thither from nearby cells. Likewise the use of dissolved food for the growth of the bud lowers the concentration of the dissolved food particles, and dissolved food begins to diffuse into the bud from the neighboring cells.

The diffusion of water and food from a cell has an important effect upon the cell from which the diffusion takes place. If the rate of diffusion of water is rapid, the dissolved foods quickly become condensed. Then changes in the food take place which are just the reverse of those described in the preceding paragraph. The simpler products unite to form starch, fats, and proteins. For instance, when sufficient water is withdrawn from a cell to make the sugars concentrated, the latter condense into starch; similarly fatty acids and bases unite eventually forming fats, and amino acids and bases unite to form proteins. These actions mean that the cell in which they take place has less "pull" on water, and also that the contained foods, if any are present, are mostly unavailable for immediate use. The rapid diffusion of foods out of the cell has virtually the same effect as the rapid diffusion of water outward. The cell is eventually left without food and without the ability to "draw" water. Large groups of cells, such as leaves, flowers, and fruits may be affected.

Now suppose that a drought begins with a hot, dry wind blowing over the plant which is in a normal condition. The movement of water

out of the stomata into the air becomes more rapid, therefore water begins to move out of the cells toward the stomata at a faster rate. As the rate of water-loss from the stomata increases, a time comes when the water reaching the foliage from the roots is much less than the outgo of water through the stomata. The reason for this may be that there is little available water in the soil, so that absorption of water by the roots is too slow to meet the increased demand of the foliage; on the other hand, it may be that the water-transportation system of the plant is too small to carry water upward from the roots fast enough to replace the loss of water from the foliage. In the first case prompt irrigation will relieve the situation; in the second case irrigation fails to prevent injury. If the outgo of water remains greater than the intake, or if the water carried upward is deficient, growth is first slowed, then stopped. The first step in the growth of cells is swelling caused by water, and since water pressure has now become lowered growth becomes slow or impossible.

Early effects of drought on the plant are not visible to the naked eye. As the water moves out of the plant the cells near the stomata and farthest from the source of water begin to lose their turgidity (water pressure). This goes on until the living substance draws away from the cell walls, first at the corners of the cell, later all around the cell. In the meantime dissolved foods in the cell are becoming unavailable, either by diffusing away or by condensing into stored products. For some time the process is capable of change back to normal (reversible), and the wilting noticed can be overcome by restoring the water balance. Later a stage in wilting is reached which is beyond repair. All free water has left the living substance and much water has been lost from the cell walls. The plant dies and often becomes yellow or brown.

So far as peas are concerned, the general effects of drought are those pictured in the preceding paragraphs. Owing to the low, massed vegetation mature peas are less liable to injury from dry winds than some other farm crops. Since the hot dry fore-summer is worst for dry winds and peas are usually planted in southern Arizona for a winter crop, the time of planting is protective here. In central and northern Arizona, summer rains are usually more prolonged, which decreases the chance of injury from dry winds.

Dying, drying, and yellowing of the foliage of peas may result from many unfavorable conditions, such as parasitic troubles and toxic soils, therefore the symptoms cannot be called symptoms of drought. When these symptoms are coupled with the occurrence of drying winds, however, diagnosis is simplified. Perhaps the greatest danger to peas from

drought comes at seeding time. Pea seeds that are permitted to dry between irrigations, which may easily happen in light soils and during drying winds, sometimes have cracked seed-coats. As a result they may fail to germinate, or may produce weak plants.

ALKALI INJURY

Pea plants existing on alkaline soil are frequently light-green to yellowish-green with dwarfed leaves and thickened stems. The cells of the skin or epidermis are smaller than those of normal plants and have thicker outer walls. The entire plant may appear dwarfed or "squatty" and remain almost stationary instead of increasing in size. Sometimes the crop ripens its vines prematurely without producing pods. In other cases the plants die in various stages of development, and examination of the underground part of the plant discloses injured, discolored roots which may appear to be "eaten off" by the alkali.

The stunting of plants grown on alkaline soils may be brought about in several ways. Alkaline soil may be "puddled" so that it becomes crusted and compact after irrigation. The work of soil bacteria is then hindered by poor aeration, and the slowing down of bacterial action in the soil is reflected in the poor nutrition of the crop. Low oxygen content in poorly aerated soils may also cause less water to be taken in by the roots, thus bringing on a shrinkage of the primary tissue (meristem) upon which growth of the roots depends (5). Very little black alkali (sodium carbonate) appears to kill the bacteria which cause nodules to form on the roots of peas. Strong solutions of sodium chloride prevent the development of a normal root system in pea plants. As previously stated under the topic of drought, dissolved substances "draw" water. Alkali salts in the soil water around the root-hairs of plants work against the absorption pull of the plant and thus make difficult the absorption of water by the plant. The living substance of plants is chemically near the neutral point and the enzymes responsible for the life processes are made and work best in a neutral or nearly neutral environment. Alkali salts which enter the plant may so change the chemical reaction of the living subtsance as to interfere with the manufacture and work of the enzymes. They may also injure the living substance, itself, by poisoning and killing it. Finally, the corrosive action of certain alkali substances in the soil may destroy the root system. Destructive action of this type in black alkali soils attributed to the presence of sodium carbonate is probably due to sodium hydroxide (2).

Peas have been grown in alkali experiments by several investigators. Hilgard (9) states that the entire legume family, to which peas belong,

is fairly tolerant of white (neutral) salts but sensitive to black alkali. Harris (8) places peas after barley, oats, wheat, alfalfa, sugar beets, and corn in the order of resistance to the ordinary mixture of alkali salts. Kearney (11) finds that germination of peas takes place as readily in white alkali soil of the sulfate type at and below 0.2 percent as in soil free from alkali. He states that a good crop of peas can be obtained where the sulfate alkali does not exceed 0.4 percent.

The control of alkali injury to peas and other crops involves the reclamation of alkali soils. Those interested in the subject are referred to the many publications of the Department of Agricultural Chemistry of the Arizona Agricultural Experiment Station.

HAIL INJURY

Although hailstorms are unlikely during the pea-growing season in southern Arizona, they may occur at that time in the central and northern parts of the State. Blows of the hailstones tear and bruise the leaves, vines, and pods. In places where the skin of the plant is broken, air enters and makes the injured spots white. The soft tissue (parenchyma) of the green parts of the plant contains the pigment (chlorophyll) which makes the starch upon which the plant depends for the carbon to build its cell walls. Since the bruised tissue resulting from the bombardment of hailstones cannot continue to make starch at the normal rate, growth of the plant is slowed and production is decreased. The spots on the pods of garden peas render them unsalable. In severe cases so much injury results from hailstorms that fields have been plowed up. The wounds in pea plants resulting from a hailstorm may become infected with parasites which seriously increase the damage to the crop.

SUMMARY

Symptoms	*Disease*	*Cause*	*Control*
Grayish powdery coating on leaves and other green parts which rubs off; diseased parts may be yellowed and killed.	Powdery mildew	Fungus—*Erysiphe polygoni*	Dust with sulfur or spray with 4-4-50 Bordeaux mixture when mildew first appears; make silage of vines after harvesting green peas; plow stubble under.
Patches of grayish violet on under side of leaf; inconspicuous yellowish spots on corresponding upper surface; infected parts may be seriously injured or killed; disease not common here.	Downy mildew	Fungus—*Peronospora viciae*	Spraying as above; destroy debris in field.
Small, roundish, brown spots on roots, stem base, and cotyledons enlarge and destroy seedlings; rotting of roots and base of stem kills mature plants; white fungus growth on infected spots, especially on deep lesions in cotyledons; disease may be confused with rhizoctoniose.	Fusarium foot rot	Fungus—*Fusarium merismoides*	Not yet known. Rotation with crops other than peas for 4-5 years, use of best seed obtainable and seed treatment, field sanitation are suggested.
Small, brown, somewhat irregular spots on stem base and root usually become considerably elongated parallel with the axis; constriction of the root, especially in young plants; stunting and death of plant; on infected roots of dead plants, sometimes on living roots, hard, roundish or somewhat irregular, and dark bodies may be found.	Rhizoctoniose, Rhizoctonia root rot	Fungus—*Rhizoctonia solani*	Treat short rows or other small areas with enough mercuric chloride solution, 1:1000, to wet soil 1 inch deep; with larger areas practice clean cultivation, rotation with small grains and sorghum, avoid excessive irrigation; do not plant peas after peas, potatoes, cotton, beans on infected land; plant garden peas on ridges and cultivate between rows as soon as possible after irrigation.

NOTE. A mercuric chloride solution must NEVER be placed in a metal vessel.

Symptoms	*Disease*	*Cause*	*Control*
Dirty white network of fungus threads on roots which finally become partly or entirely rotted; skin or cortex of roots slips off; plants killed in circular spot in field; velvety white patches of fungus often appear on surface of soil, especially during summer rains, and become tan with age; wilting and death of cotton, alfalfa, and other taprooted plants in circular spots also usually indicate presence of Texas root rot.	Texas root rot	Fungus—*Phymatotrichum omnivorum*	Infected plants cannot be saved. Immediately disinfect very small root rot spots by soaking soil to depth of 4 feet with 3- to 4-percent formaldehyde. Single large root-rot spot should be separated from clean part of field with barrier (a) 6-8 rows of sorghum, or (b) trench 1 to 2 feet wide and 4 feet deep filled with soil soaked with used automobile cylinder oil or thoroughly mixed with a liberal quantity of bluestone. Fields spotted with root rot should be thoroughly dry-worked (no irrigation) for a year *or* planted to sorghum and small grains for 2-4 years. Subsoiling and heavy applications of barnyard manure over a period of 3 or more years help. *Taprooted weeds must be kept out.* Examination of the soil for resting bodies of the root-rot fungus is advisable before making an extensive root rot eradication campaign
Small, water-soaked spots on aboveground parts of plant which become dark with age; seedlings fall to the ground or wilt; yellowing of leaves on older plants, base toward top. Flowers and young pods may be killed, mature pods spotted.	Bacterial blight	Bacterium—*Phytomonas pisi*	Use best seed and treat seed in solution of formaldehyde, 1 pint to 22 gallons of water, for 20 minutes, or in mercuric chloride solution, 1-1000 10 to 20 minutes; or with organic-mercury dust according to directions on package. Use of selected seed, seed plot, rogueing, and windbreaks is advisable.

Symptoms	*Disease*	*Cause*	*Control*
Stunting, shrivelling and death of plants; numerous knots *in* roots.	Root knot	Roundworm—*Caconema radicicola*	Soak very small infected spots of soil with 4-5 percent formaldehyde after pulling and destroying infected plants. Infested fields should be thoroughly dry-worked during the hottest and driest part of the year *or* planted to immune or resistant crops *only* for 2 or more years.
Marginal "burning," wilting and yellowing of leaflets and vines, during or immediately after hot, dry winds; stunting of plants, yellowing of foliage and death accompanying low available moisture in soil.	Drought effect	Physiological	Use of windbreak. Correct irrigation practice and addition of organic matter to the soil.
Light-green to yellowish foliage, dwarfed leaves and thickened stems; dwarfed or "squatty" plants; restricted or poorly developed root system, when the symptoms occur in peas growing on moist soil; roots may be discolored, ulcerated, or appear to be "eaten off."	Alkali effects	Physiological	Apply to Arizona Agricultural Experiment Station for instructions on reclamation of alkali land.
Torn or bruised spots on leaves, vines and pods, which may be white water-soaked; the spots may become rotted following infection, thereafter assuming an entirely different appearance, or they may become corked around the margin or over the surface.	Hail effects	Physiological	

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